NACA RM L9L19

MAY 1950

NACA

RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF THE EFFECT OF THICKENING THE

AILERON TRAILING EDGE ON CONTROL EFFECTIVENESS FOR

SWEPTBACK TAPERED WINGS HAVING SHARP-

AND ROUND-NOSE SECTIONS

By H. Kurt Strass and Edison M. Fields

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

NACA LIBRARY

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
May 2, 1950

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF THE EFFECT OF THICKENING THE

AILERON TRAILING EDGE ON CONTROL EFFECTIVENESS FOR

SWEPTBACK TAPERED WINGS HAVING SHARP-

AND ROUND-NOSE SECTIONS

By H. Kurt Strass and Edison M. Fields

SUMMARY

An investigation has been made, by means of rocket-propelled test vehicles, of the rolling effectiveness at transonic and supersonic speeds on a 38.1° sweptback tapered wing having NACA 0010-64 airfoil sections and equipped with partial-span ailerons of true contour and modified to a flat-side blunt trailing-edge shape. The results are compared with previous results for a similar modification to a wing having circular-arc sections. The results indicated that, for both airfoil sections with a control deflection of 5°, the original true-contour ailerons, which had trailing-edge angles of 21° for the circular-arc section and 17° for the round-nose section, showed a sharp loss in rolling effectiveness between Mach numbers of 0.9 and 1.0 with a reversal of control at a Mach number of approximately 0.95. Modifying the aileron by thickening the trailing edge to one-half the aileron thickness at the hinge line, which reduced the trailing-edge angle to approximately 8°, eliminated the control reversal and in general improved the effectiveness in the transonic range for both airfoil sections, although at some sacrifice in drag.

INTRODUCTION

The Langley Pilotless Aircraft Research Division is conducting an investigation of wing-aileron control at subsonic, transonic, and supersonic speeds by means of rocket-propelled test vehicles in free flight. Investigation of an aileron on a tapered sweptback wing having a circular-arc section with a trailing-edge angle of 21° indicated a

CONFIDENTIAL

control reversal near Mach number 1.0 which was eliminated by modifying the aileron to a flat-side blunt trailing-edge shape which effectively reduced the trailing-edge angle. This phenomenon has been investigated further with a round-nose section and the results are presented herein and compared with previous results.

The tests were made with 0.171-chord outboard half-span ailerons with true contour and also with the trailing edge increased to one-half the thickness at the hinge axis. The wing had an aspect ratio of 3.61, a taper ratio of 0.455, a sweepback angle of 38.1° measured at the quarter-chord line, and an NACA 0010-64 airfoil section normal to the 44.8-percent-chord line. Drag as well as control effectiveness was measured.

SYMBOLS

A aspect ratio $\left(\dfrac{b^2}{S_1}\right)$

b diameter of circle swept by wing tips (2.23 ft)

$\bar{c}$ mean aerodynamic chord parallel to model center line (0.625 ft)

C_{D_T} total drag coefficient based on total exposed wing area, S

i_w wing-chord-plane incidence angle, degrees

M free-stream Mach number

m couple, applied at wing tip in a plane parallel to model center line and normal to wing-chord plane, inch-pounds

p model rate of roll, positive if clockwise when viewed from rear, radians per second

$\dfrac{pb}{2V}$ rolling effectiveness parameter

R Reynolds number based on $\bar{c}$

S total exposed wing area (1.563 sq ft)

S_1 area of two panels taken to center line (1.378 sq ft)

V velocity of model along flight path, feet per second

δ_a deflection of each aileron from wing-chord plane, measured in a plane parallel to model center line, degrees

θ angle of wing twist (produced by m) at any section along wing span in a plane parallel to free stream and normal to wing-chord plane, radians

$\frac{\theta}{m}$ wing-torsional-stiffness parameter in a plane parallel to model center line, radians per inch-pound

λ taper ratio

TEST VEHICLE AND TESTS

The geometrical arrangement of the test vehicles used in this investigation is given in table I and figures 1 and 2. The model finish consisted of several coats of clear lacquer rubbed almost glass-smooth. The torsional-rigidity characteristics for the wing plan form tested are presented in figure 3. The parameter $\frac{\theta}{m}$ was obtained by applying a known couple at the tip of the wing and then measuring the variation of twist along the span. The torsional rigidity as given in figure 3 has been shown by unpublished data to be sufficiently rigid to limit the loss of control effectiveness to a maximum of 20 percent at a Mach number of 1.8.

The test vehicles were of the same simple and relatively inexpensive construction as has been used previously and are described in reference 1. The measured values of aileron deflection and wing incidence are estimated to be within ±0.1° and ±0.05°, respectively, of the actual values. The test vehicles were propelled to approximately M = 1.7 by a two-stage rocket-propulsion system. All the data were obtained during the coasting period following burnout of the sustainer motor. The flight-path velocity was measured by the use of the CW Doppler radar technique and the rolling velocity by the use of spinsonde radio equipment. Atmospheric data were obtained from radiosonde records. Drag information was obtained by the differentiation of the flight-path velocity curve against time. A more complete description of the technique is given in references 2 and 3.

ACCURACY

The estimated accuracies for the parameters measured in this investigation are as follows:

$\frac{pb/2V}{\delta}$ (due to limitations on model construction and
measurement accuracy) . . . . ±0.00025

$\frac{pb/2V}{\delta}$ (due to limitation in instrumentation) . . . . ±0.0001

C_{D_T} . . . . ±0.0020

M . . . . ±0.010

CORRECTIONS

Because of the limitations in constructional accuracy, the resulting small deviations from the design values were measured and the data were corrected to unit aileron setting and zero wing incidence to allow direct comparison between models. The rolling effectiveness parameter $\frac{pb}{2V}$ was assumed to vary linearly with aileron deflection. Errors in incidence were corrected by assuming that a steady-state rolling condition existed when the rolling moment caused by incidence was equal to the damping moment. In addition, the lift-curve slope at any position along the span due to incidence was assumed to be constant and equal to the lift-curve slope due to damping. The resulting general equation is as follows:

$$\Delta \frac{pb}{2V} = \frac{2i_w}{57.3}\left(\frac{1 + 2\lambda}{1 + 3\lambda}\right) = 0.0281i_w$$

where

i_w measured wing incidence in degrees

λ taper ratio, tip chord to extended chord at model center line (0.455)

The correction for incidence was assumed to be constant throughout the entire Mach number range. This correction has been verified experimentally for an unswept rectangular plan form of aspect ratio 3.7 except for the region around $M \approx 0.95$ where a small abrupt discontinuity occurs. (See fig. 4.)

The effect of the moment of inertia about the roll axis on the measured values of $\frac{pb}{2V}$ was assumed to be negligible. (See reference 1.) The $pb/2V$ values from reference 1 when plotted in this paper were corrected to $\delta_a = 5^\circ$ streamwise to facilitate direct comparison.

RESULTS AND DISCUSSION

The variation of Reynolds number with Mach number is shown in figure 5. A comparison of the control effectiveness of the two types of ailerons is presented in figure 6 as curves of the control effectiveness parameter $pb/2V$ against Mach number. The original true-contour aileron exhibited a very abrupt loss of control accompanied by a slight reversal in the range between $M \approx 0.9$ and 1.0. This condition was previously encountered on a wing of similar geometric characteristics but with a

different airfoil section (10-percent circular arc). By increasing the
thickness at the trailing edge to one-half the thickness at the hinge
axis (reference 1), the aileron control was improved. The same
technique was used in this investigation and yielded approximately the
same results. The improvement in control is confined largely to the
speed region below M ≈ 1.2. In figure 7, a direct comparison is made
of the results from the two series of tests. For the true-contour
aileron, the curves of $\dfrac{pb/2V}{\delta}$ from the present tests and from refer-
ence 1 agreed well except for a limited region between M ≈ 0.9 and 1.2
where the aileron from the present tests was more effective. The blunt
trailing-edge control used in the present tests was slightly more
effective throughout most of the speed range than was the same type of
control from reference 1. In general the data seem to indicate that
the effectiveness of a given type of control is only slightly affected
by the thickness distribution of the forward portion of the airfoil.
The use of the blunt trailing-edge aileron caused a large increase in
total drag coefficient below the speed of sound; however, the drag-
coefficient increase above the speed of sound was less (see fig. 8).

CONCLUDING REMARKS

        A free-flight investigation at transonic and supersonic speeds of
the rolling effectiveness of ailerons on a sweptback tapered wing
having a round NACA 0010-64 section with a trailing-edge angle of 17°
indicated that a large abrupt decrease in aileron effectiveness
accompanied by reversal occurred in the transonic region. The loss of
effectiveness was similar to that reported previously with a circular-
arc section having a trailing-edge angle of 21°.

        An effective means of reducing this loss of control for either
airfoil section was the use of a flat-side aileron, the contour of which
was modified by thickening the trailing edge to a value of one-half the
thickness at the hinge line.

        The drag of the wing was appreciably increased by the modification
to the aileron at subsonic speeds, although at speeds greater than a
Mach number of 1.0 the drag increase was small.

Langley Aeronautical Laboratory
        National Advisory Committee for Aeronautics
                Langley Air Force Base, Va.

REFERENCES

1. Sandahl, Carl A.: Free-Flight Investigation at Transonic and Super-
     sonic Speeds of the Rolling Effectiveness of Several Aileron
     Configurations on a Tapered Wing Having 42.7° Sweepback. NACA
     RM L8K23, 1949.

2. Sandahl, Carl A.: Free-Flight Investigation of Control Effectiveness
     of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic,
     and Supersonic Speeds to Determine Some Effects of Wing Sweepback,
     Taper, Aspect Ratio, and Section Thickness Ratio. NACA RM L7F30,
     1947.

3. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation
     of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons
     at High Subsonic, Transonic, and Supersonic Speeds to Determine
     Some Effects of Section Thickness and Wing Sweepback. NACA
     RM L7D02, 1947.

TABLE I

GEOMETRIC CHARACTERISTICS

Aspect ratio	3.61
Total exposed wing area, square feet	1.563
Taper ratio	[a]0.455
Mean aerodynamic chord, $\bar{c}$, feet	0.625
Sweepback of wing L.E., degrees	41.6
Sweepback of wing c/4, degrees	38.1
Sweepback of wing T.E., degrees	25.2
Ratio of aileron span to wing span	[a]0.5
Average moment of inertia about roll axis, slug-feet^2	0.0768
Location of hinge axis, percent free-stream chord	82.9
Airfoil section normal to 44.8-percent free-stream chord	NACA 0010-64
True-contour aileron trailing-edge angle, normal to 44.8-percent free-stream chord, degrees	17
Modified aileron trailing-edge angle, normal to 44.8-percent free-stream chord, degrees	7.8

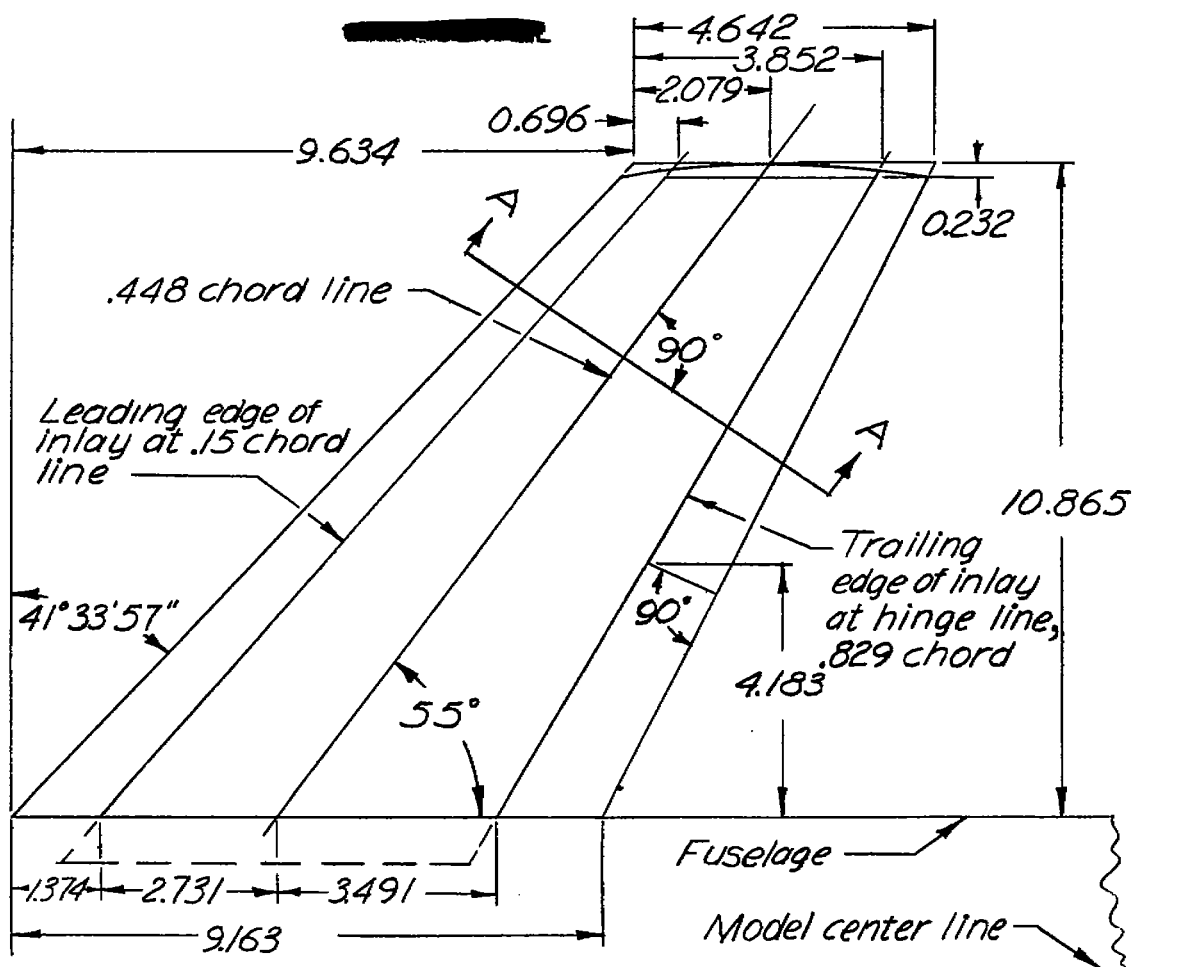[a]Obtained by extending wing to center line of fuselage.
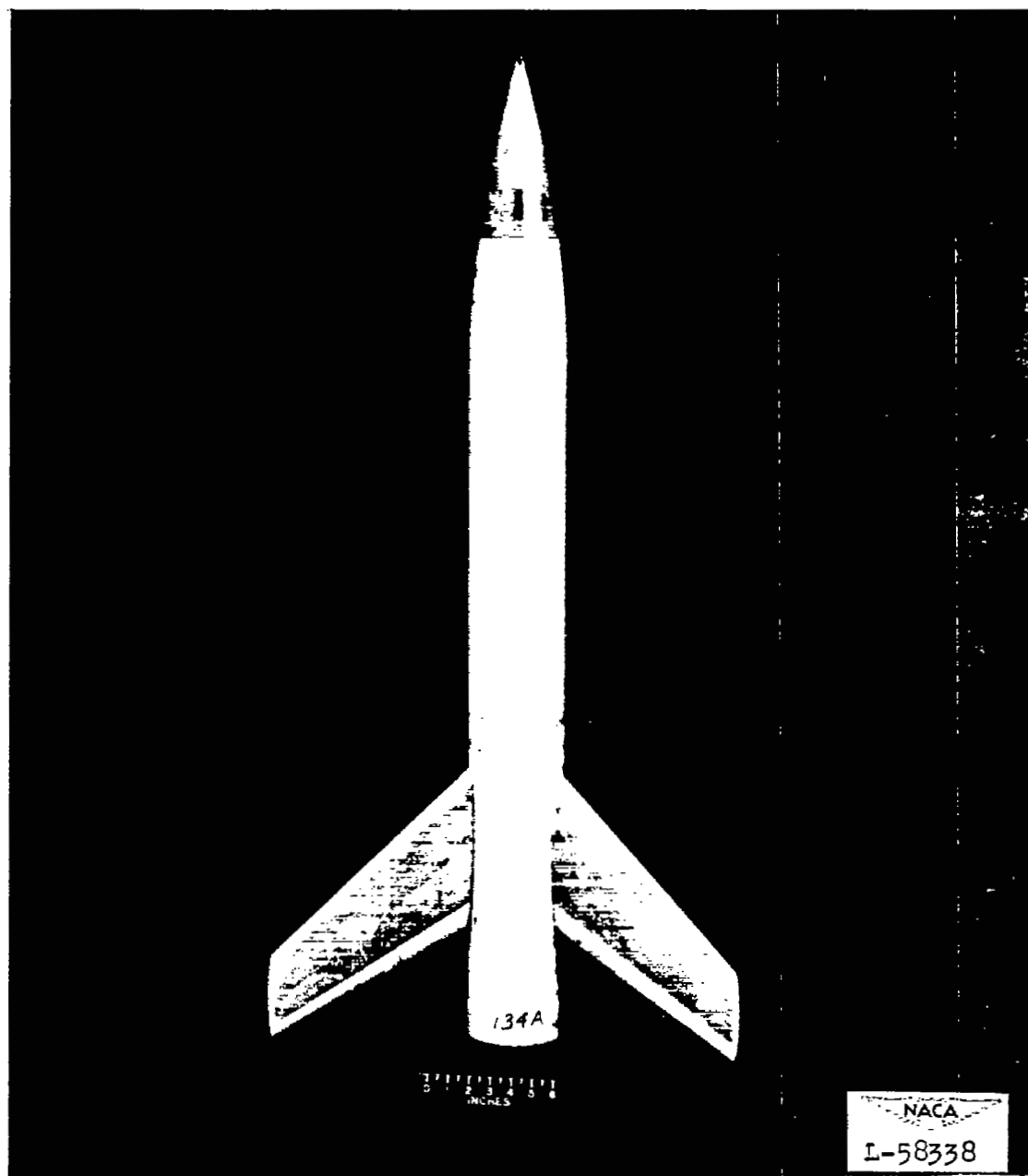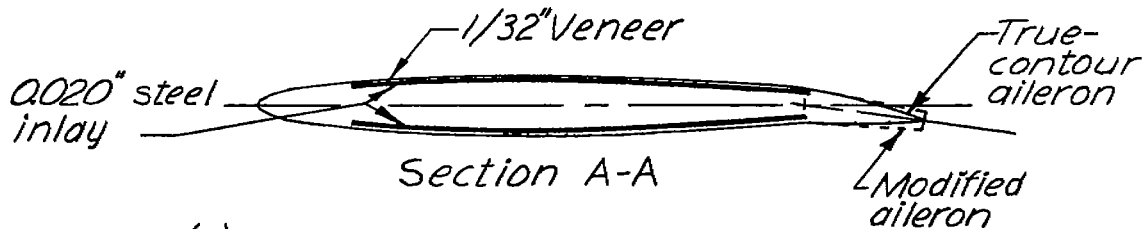
Figure 1.- Photograph of typical model.
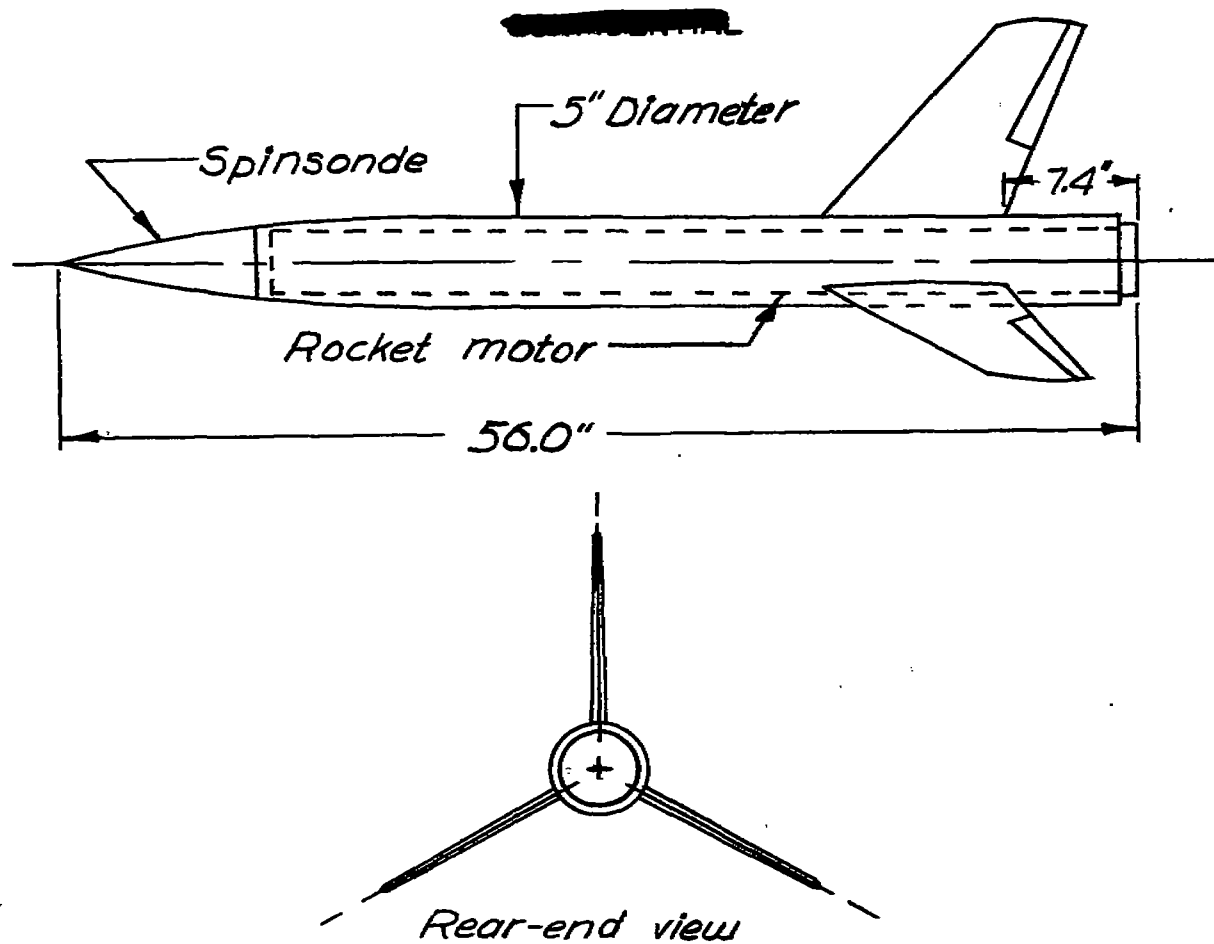
(a) Location of wings on body.

Figure 2.- General arrangement of models.

All dimensions in inches

Chord measurements parallel to model center line

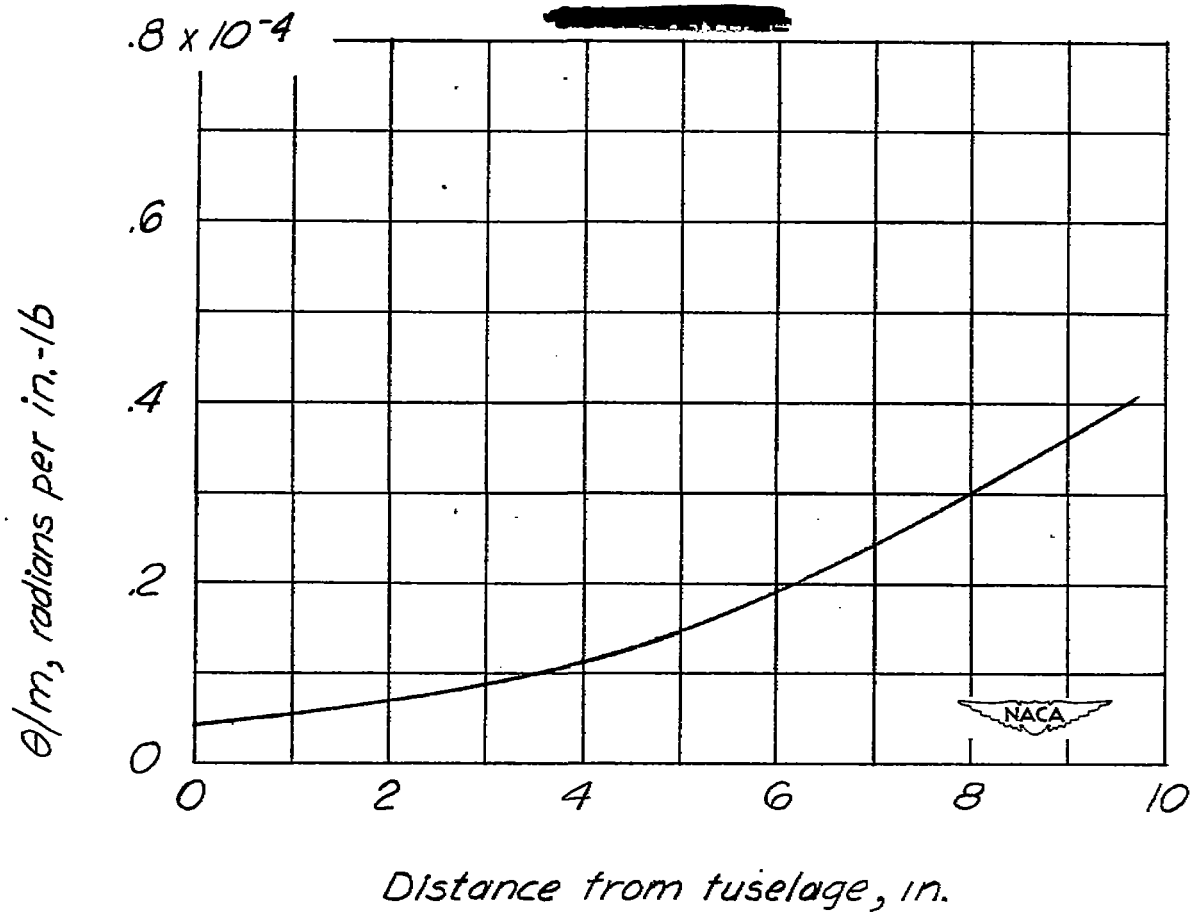Section A-A

(b) Wing planform and profile.

Figure 2.- Concluded.

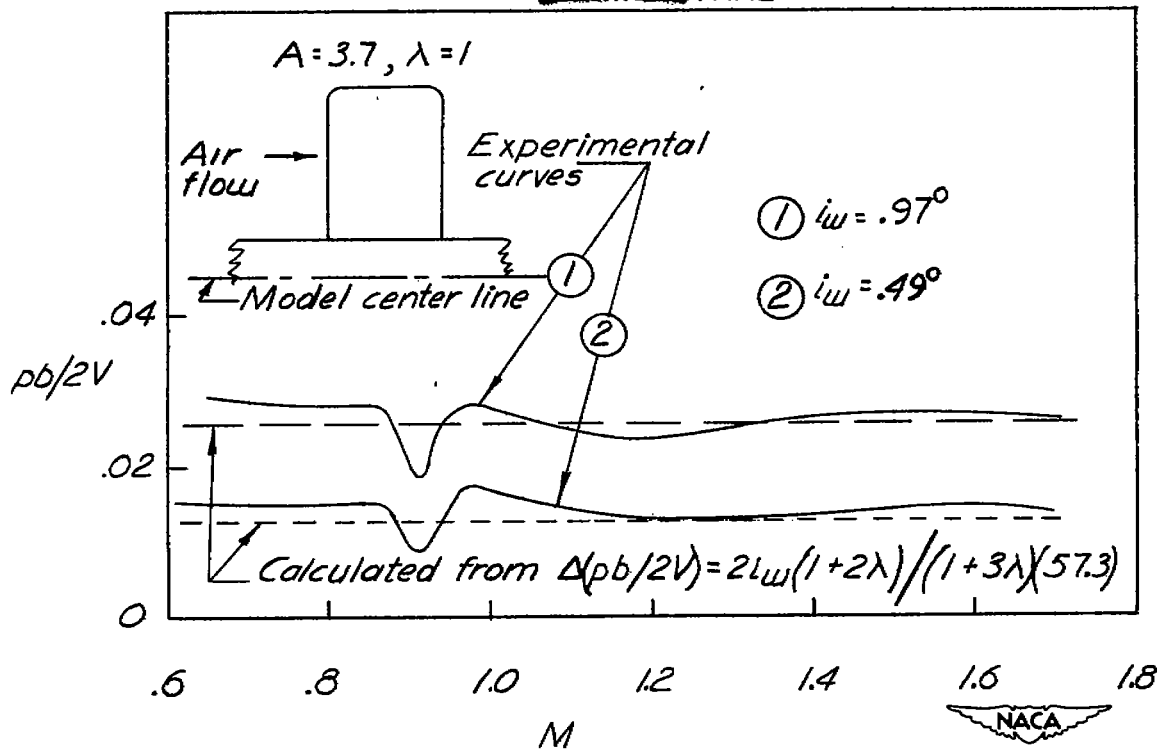Figure 3.- Variation of torsional-stiffness
parameter θ/m with span.

Figure 4. - Comparison (for unswept planform) of
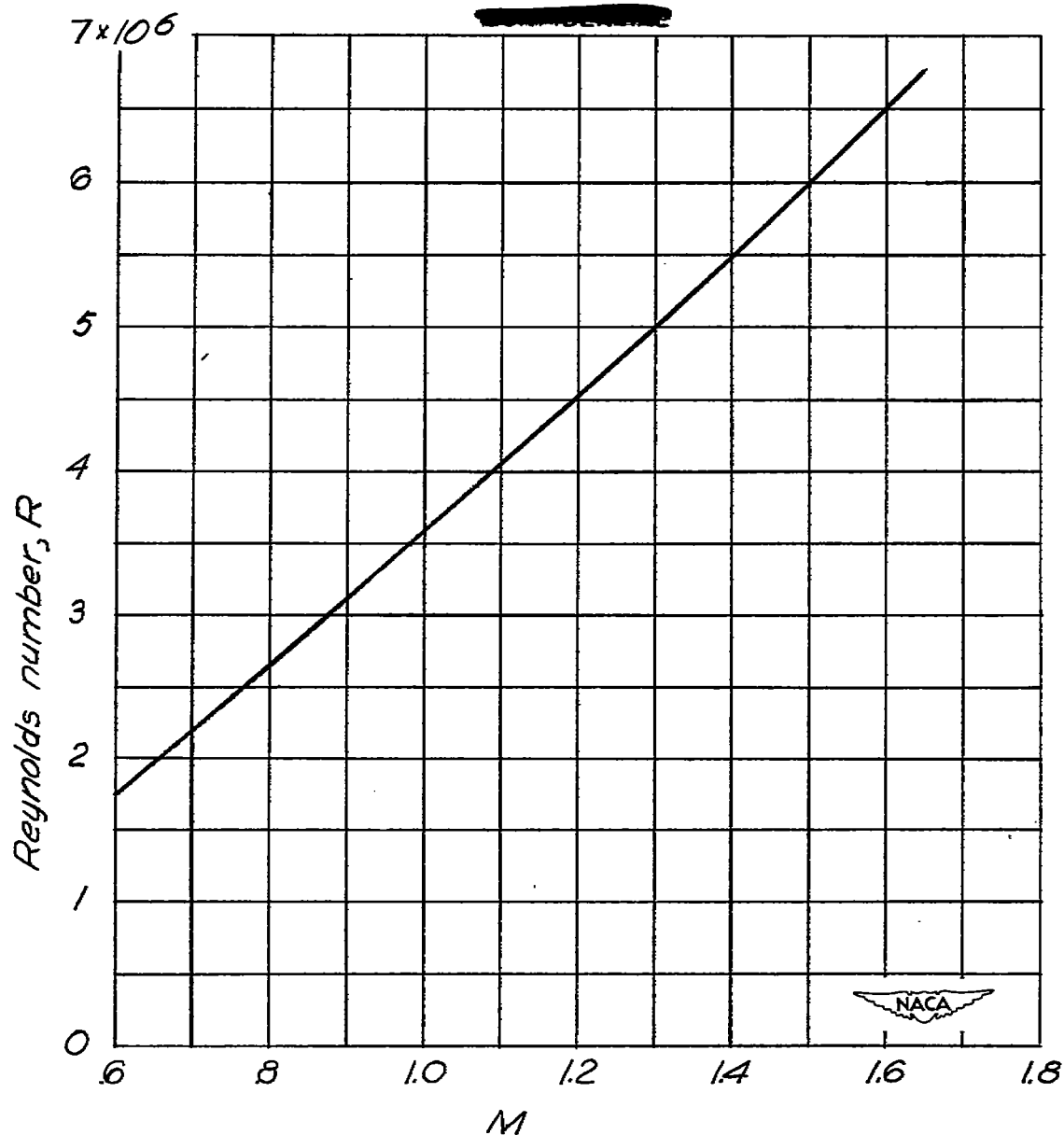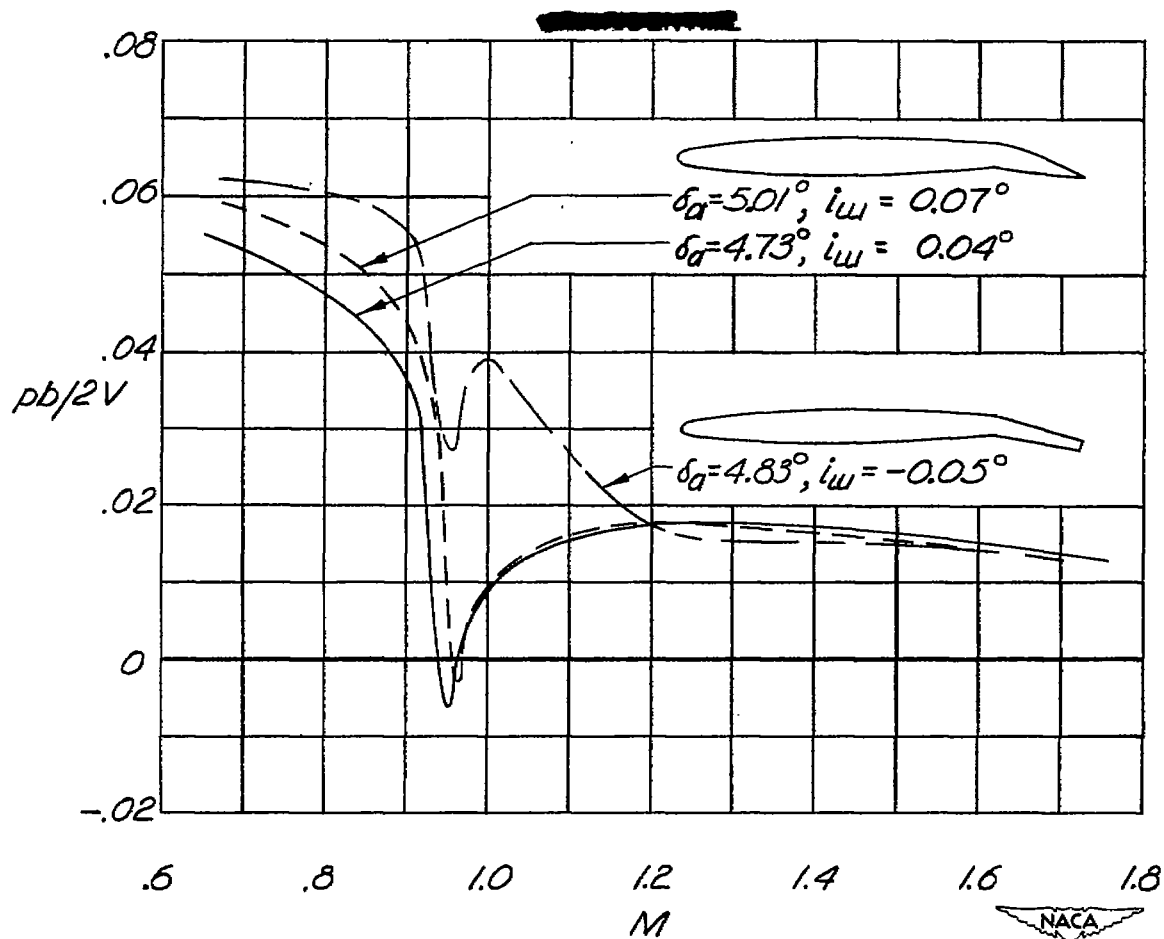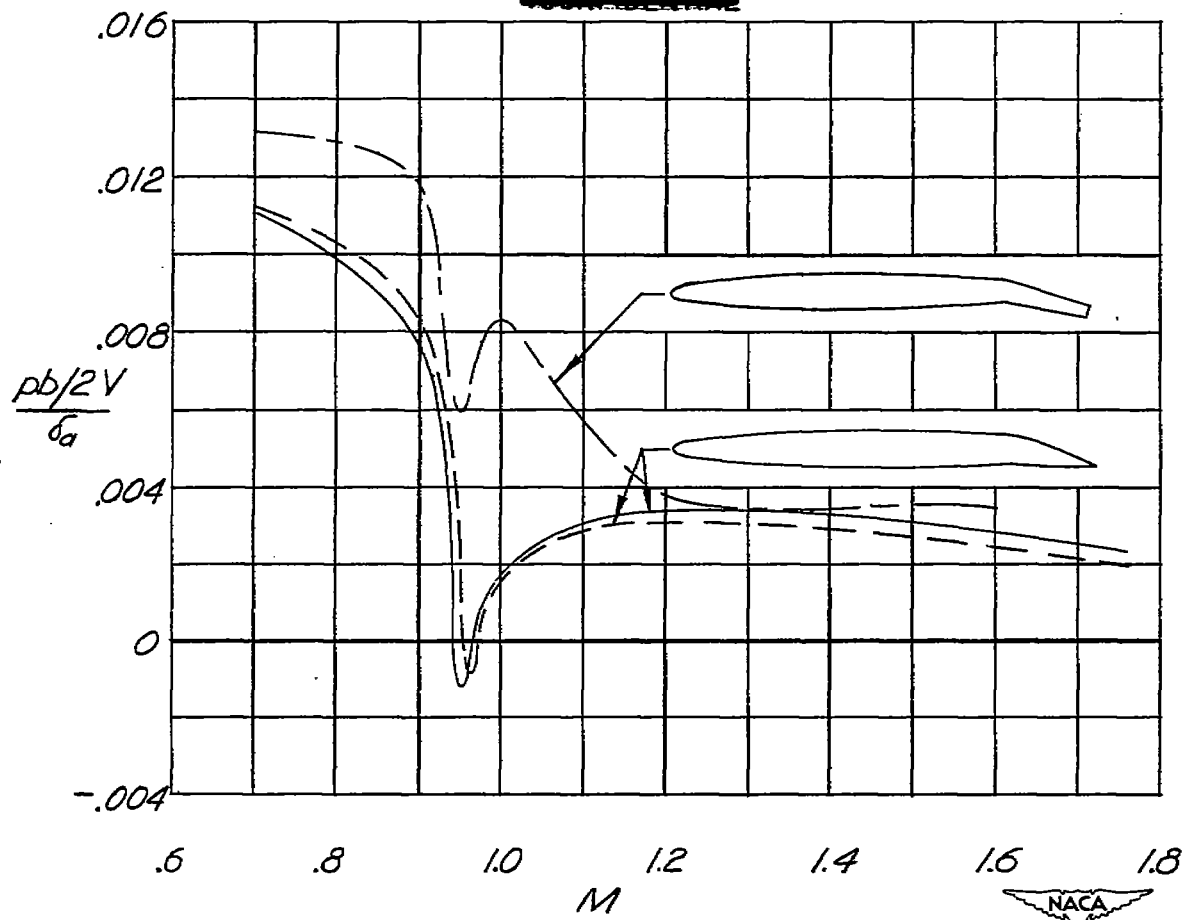theoretical and experimental pb/2V
values due to incidence of wing.

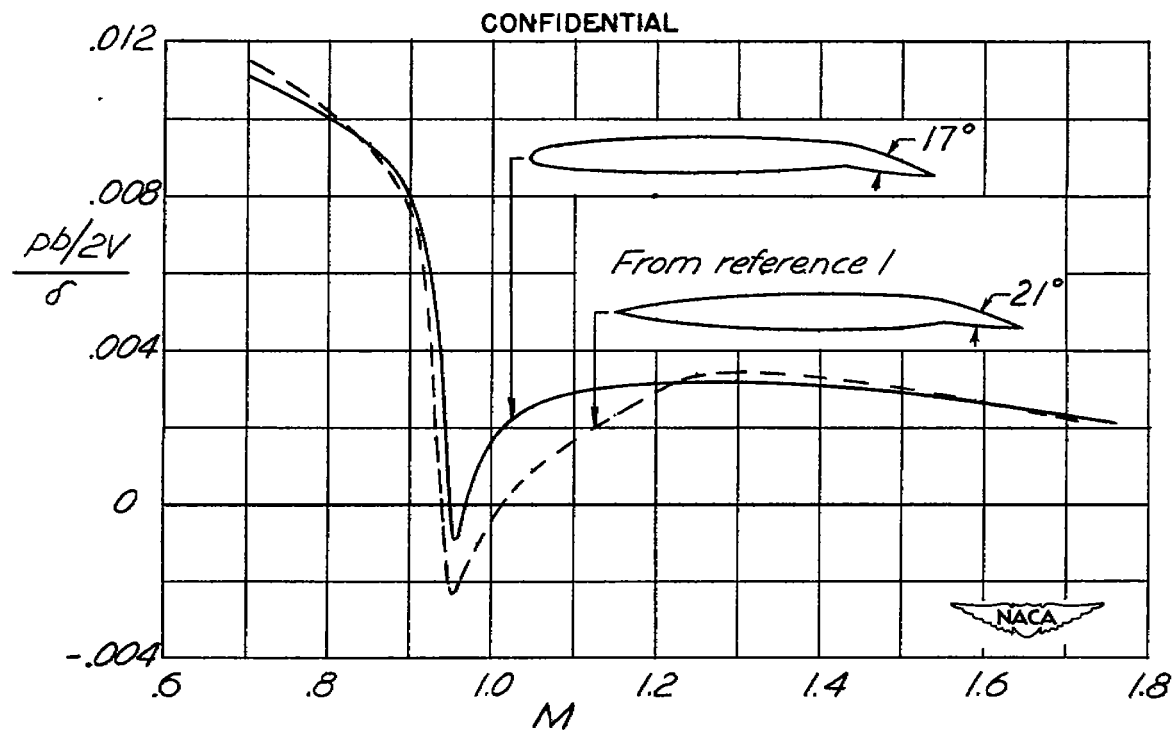Figure 5.- Variation of Reynolds number with
            Mach number.

(a) Before correcting to $i_w = 0°$ and
     δ_a = unit deflection.

Figure 6. - Variation of rolling effectiveness
            with Mach number.

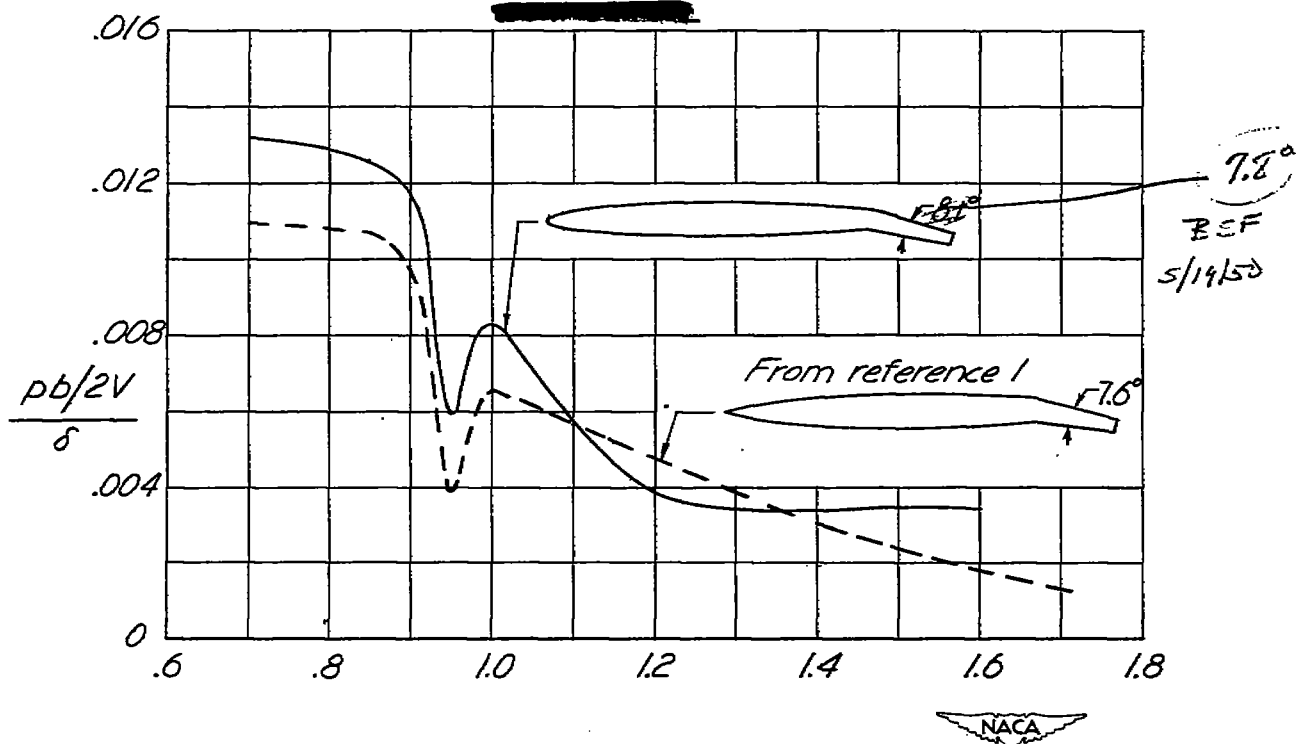(b)   After correcting to $i_w = 0°$ and
δ_a = unit deflection.

Figure 6.- Concluded.

CONFIDENTIAL

(a) Comparison of true-contour aileron
effectiveness on circular-arc and
NACA 0010-64 airfoils.

Figure 7.- Comparison of aileron effectiveness with
that of reference 1.

(b) Comparison of wedge-type aileron
    effectiveness on circular-arc and
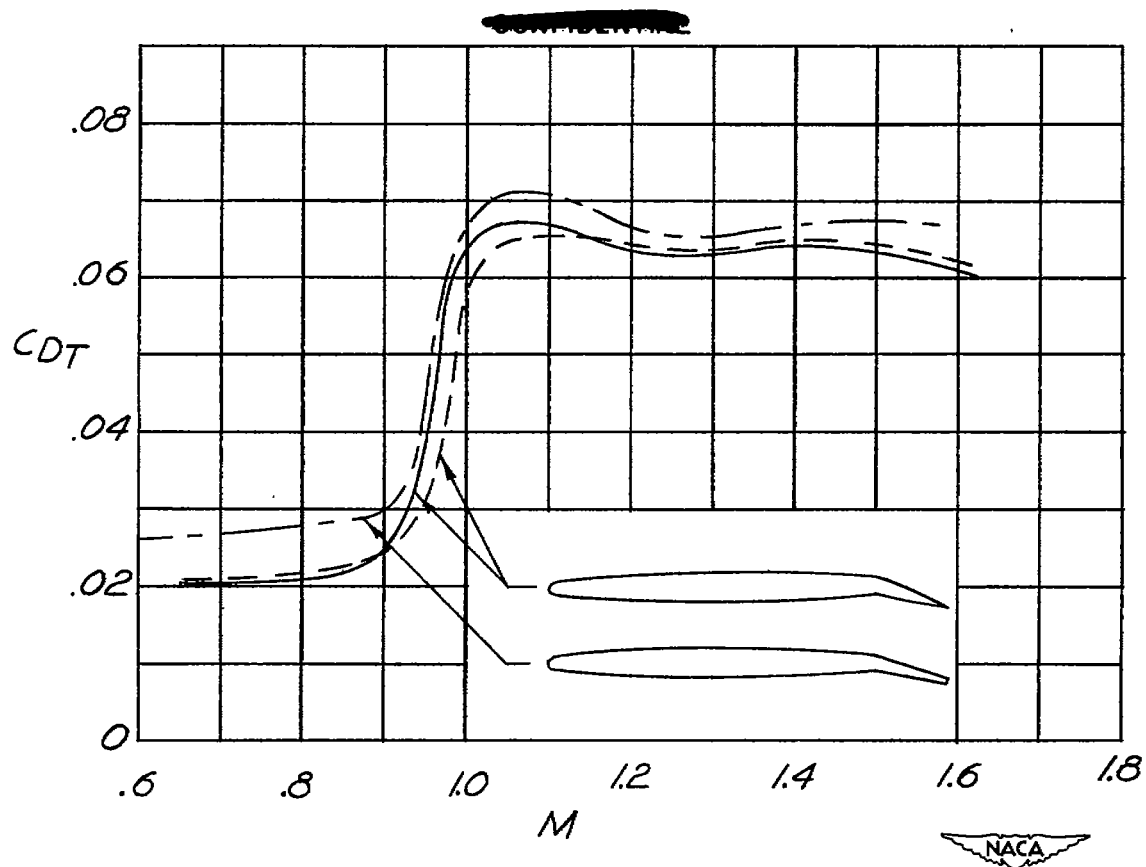   NACA 0010-64 airfoils.

Figure 7. - Concluded.

Figure 8.— Variation of total drag coefficient with
Mach number.